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A Survey of New England Sheep Producers

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A Survey of New England Sheep Producers

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Abstract

Many factors experienced by the dam during gestation impact offspring BW, body composition, and metabolism, thereby affecting productivity. Several sources of information are available to producers for guidance in managing their breeding flocks; however, it is unknown if sheep producers in New England utilize these resources. In previous USDA surveys of sheep producers, New England was not included, thus leaving a gap of knowledge. Our objective was to conduct a survey of New England sheep producers to determine flock size, breeds, pregnancy detection methods, feeding management practices, and producer learning styles. In particular, we wanted to determine if flock size influenced management practices, and if flock purpose (eg., meat, fiber) and feed type (eg., hay) influenced feeding management. A 12-question survey was developed and disseminated to New England sheep producers via Qualtrics using e-mail survey links, with a 33.2% response rate (n = 96 responses). Data were analyzed using SPSS. Of the respondents, 61.5% have flocks sizes of 11 to 50 sheep. Most producers (63.5%) maintain one breed of sheep; however, larger flocks (> 50 sheep) are more likely to maintain multiple breeds ($P < 0.05$). The largest percentage (40.6%) uses their sheep for both meat and fiber production, 38.5% for meat only, and 20.8% manage sheep for fiber only. Spring (January to May) is the primary (59.4%) lambing season. The majority (76.0%) of New England sheep producers do not have their feed chemically analyzed for nutrient composition, which presents an opportunity for improved feeding management. There were correlations ($P < 0.05$) between flock size and flock purpose, flock size and number of breeds owned, flock size and feed type, feed types and number of feed types used, feed type and feed analysis, feed type and source of feed information, and source of feed information and state. In conclusion, New England sheep producers have flocks of varying size and purpose, and would likely benefit from improved Extension outreach education designed to support the region’s specific needs.

Introduction

I. Economic & Nutritional Value of Sheep

As of 2017, there were 5.2 million sheep in the United States. Over 3 million of these animals are breeding ewes, and 1.3 million are market animals used for meat production (NASS, 2017). In 2016, the value for shorn wool in the United States was $37.2 million for 25.7 million pounds of wool (NASS, 2017). While the national wool value and price per pound has decreased, both values have increased in New England (NASS, 2017). Between 2016 and 2017, sheep production at the national level decreased by 2%; however, during this same period of time, sheep production in New England increased by 2% (NASS, 2017). The New England lamb crop also increased by 4% from 2015 to 2016 (NASS, 2017). Additionally, lamb meat imports in the United States have increased over the past decade and account for nearly one-half of lamb consumed within the United States (Agricultural Marketing Resource Center, 2017). This demonstrates that there is a demand for sheep products and the potential for growth of the American sheep industry.

Since the mid-1940s the demand for wool in the United States has declined due to the increased accessibility of synthetic fibers and U.S. wool production has declined as lamb inventory has decreased (Agricultural Marketing Resource Center, 2018). Wool possesses a variety of characteristics that contribute to its quality grading, such as fineness, fiber diameter, uniformity, and has been graded through the use of three different systems throughout history (Mathis and Faris, 2002). Fine wool production accounted for half of U.S. wool production in 2017, with a total value of $36.4 million (NASS, 2017). The major competitors for U.S. wool are Australia and New Zealand, as the top two largest exporters of wool globally (Agricultural Market Resource Center, 2018).

In a 2011 study modeling the impact of the sheep industry on the United States economy, the sheep industry's total economic value was estimated at $4.4 billion (Shiflett, 2017). However, a refined model was used in a follow-up study conducted in 2017, which represented the total economic impact of the national sheep industry to be $5.72 billion (Shiflett, 2017). The second model suggests that despite a numerical downsizing of the industry, its economic power has actually continued to grow. The 2017 model also indicated that for every $1 invested in sheep production and related activities, $2.42 in labor income was generated for employees of the sheep industry (Shiflett, 2017). Additionally, for every $1 of total sheep industry production, $2.87 is added to the United States economy through industry profit and the buying power of industry laborers (Shiflett, 2017). The added value of the sheep industry creates a "ripple" of economic impact and increased economic activity which allows for a regional industry in the hundreds of millions of dollars to support a total contribution to the national economy in the billions of dollars. This contribution to the national economy comes in the form of employees of the sheep industry turning their incomes towards buying necessities and luxuries, contributing further to the incomes of other industries' employees.

Lean red meat, which includes lamb and mutton, is a source of high quality bio-available protein, minerals and essential vitamins, such as vitamin B12, niacin, vitamin B6, iron, zinc, and phosphorous (Williams, 2007; Sebsibe, 2008). Lamb and mutton are also dietary sources of long-chain omega-3 polyunsaturated fats, as well as other vitamins and minerals such as selenium, copper, magnesium, iron, calcium, and vitamin A (Williams, 2007). Protein, fats, and micronutrients are needed by all organisms for good health throughout life (Williams, 2007; Sebsibe, 2008). In 100 grams of lamb or mutton there are nearly one-half the recommended daily intake (RDI) of protein and zinc, at least 25% of the RDI of iron for adult men, 20 to 40% of the

RDI of phosphorous, and between 25 to 50% of the RDI of many B vitamins (Williams, 2007; U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). Trimmed lean red meat is also low in fat and sodium with moderate cholesterol content, and lamb and mutton contain more omega-3 fatty acids than chicken and pork (Williams, 2007). In addition to the major nutritional compounds, red meat also contains other biologically useful bioactive compounds, such as taurine and carnitine, which are notably abundant in sheep muscle (Williams, 2007). Lamb is a better source for protein, vitamins, and minerals in comparison with non-meat sources of protein (Williams, 2007). Considering the nutritional value of sheep meat and the necessity of importing up to 50% of the national demand for lamb, the sheep industry is a valuable source of nutrition and economic power with the potential for growth.

II. The Impending Global Food Crisis

As of 2009, roughly 14% of the global population lacks access to enough protein and energy through their diets, with a greater percentage suffering from some type of micronutrient deficiency (Alexandratos and Bruinsma, 2012). Food producers struggle to balance resource competition, the need to produce an increased volume of products, and the need to ameliorate environmental impacts of agriculture (Godfray et al., 2010). Simultaneously, the demand for animal food products continues to increase as the population grows (Godfray et al., 2010). By 2050 the increase in global population is expected to require 70 to 100% more food than is currently available, surpassing the world’s current ability to meet the nutrient needs of the global population (Parfitt et al., 2010; Koba, 2014; Steensland and Zeigler, 2017). Without a change in the sustainability and efficiency of how food is produced, there is the risk of increased difficulty providing nourishment to parts of the world as early as 2030 (Steensland and Zeigler, 2017).

There are several methods that could help improve food production on global and regional scales, such as site-specific methods to close crop yield gaps, sustainable farming methods, increasing production limits and feed efficiency among livestock, reducing food waste, and changing human diets (Godfray et al., 2010). While improving food production to meet the increasing demands of a growing global population is a complex problem, livestock production efficiency can be improved by better understanding the differences between current management practices and those practices needed to efficiently improve livestock quality and yield. Feed management, and especially feed management during gestation, is a key management practice for livestock species as both pre- and post-natal nutrition play a large role in the productivity of livestock and their offspring.

The effects of maternal nutrition during gestation were first observed and reported in humans, and subsequently studied in animals, giving rise to the thrifty phenotype hypothesis (Hales and Barker, 2001). The thrifty phenotype hypothesis was first proposed by Hales and Barker in 1992 and suggests that the in utero environment to which the fetus is exposed programs the offspring to thrive in a similar postnatal nutritional environment. This occurs through the alteration of metabolic processes in the fetus to produce adaptations for the expected postnatal nutritional landscape. These adaptations produce increased disease and health risks for the offspring when the actual postnatal nutrition of the offspring does not match this programmed metabolic expectation (Hales and Barker, 2001). This hypothesis was first formulated based on observational studies of human health after gestational exposure to famine (Hales and Barker, 2001).

The Dutch famine is the most well-known and frequently studied cohort of famine-exposed individuals, as the food shortage was due to the embargo on food transports to the

Western Netherlands put in place by the occupying German force during World War II (Banning, 1946; Painter et al., 2008). During this food shortage, adult rations were cut to less than one-quarter of pre-famine ration, as low as 400 calories per day (Painter et al., 2008). There have been post-famine epidemiological associations between the development of type 2 diabetes, due to reduced insulin secretion and insulin resistance, and poor growth during gestation and infancy, leading to permanent changes in insulin:glucose metabolism and metabolic syndromes (Hales and Barker, 2001). While livestock species in general and sheep specifically do not develop diabetes, insulin resistance or other metabolic disturbances due to poor maternal diet during gestation can occur, creating a reduction in production efficiency in these animals.

In addition to the effects of maternal nutrition on the offspring, there is also evidence that grandmaternal nutrition has a role in health and chronic disease incidence (Painter et al., 2008). The Dutch famine cohort is well-tracked and has been interviewed regarding the health of grandchildren of men and women who were expecting children during the famine (Painter et al., 2008). This maternal in utero exposure to famine was associated with increased offspring adiposity and poor health due to 'other' causes not including cardiovascular or metabolic disease; however, the lack of evidence for cardiovascular or metabolic disease was likely due to the grandchildren cohort having an average age of 35, as the prevalence of such diseases increase above 50 years of age (Kraja et al, 2006; Painter et al., 2008). The implications for this in livestock species suggest that once nutrition management becomes ideal after previous poor management, the effects of previous poor nutrition during gestation can have effects on flock productivity that last beyond a single generation.

III. Maternal Programming Research

The primary animal models used to study maternal programming based on gestational diet involve rodents, guinea pigs, and sheep (Aiken et al., 2016). This is useful for those researching sheep production as much of the literature deals specifically with maternal programming in a sheep model. The uterine environment during gestation influences offspring development as much as genetics do (Wilmut and Sales, 1981; Barnes, 2000; Gluckman and Hanson, 2004; Godfrey and Barker, 2007). Over- or under-nourishment of dams during gestation can instigate alterations in fetal developmental programming, which has been shown to affect the long-term production performance of livestock (Bispham et al., 2003, 2005; Benyshek et al., 2004; Bieswal et al., 2006; Yan et al., 2011; Hoffman et al., 2014, 2016a, 2016b; Reed et al., 2014). Several mechanisms for nutrition based maternal programming have been proposed and demonstrated in animal models, including structural alterations to tissues and organs, epigenetic programming of genes, glucocorticoid effects, and acceleration of the cellular aging process (Ulrey et al., 2005; Tong et al., 2008; Altmann et al., 2012; Funston and Summers, 2013; Yang et al., 2013; Aiken et al., 2016).

In a previous study examining over-feeding ewes during gestation, lambs from overfed dams were found to have increased heart size at birth and increased birthweight, as well as increased average daily gain and BCS post-weaning (Hoffman et al., 2014, 2016a, 2016b). In this previous study restricted maternal nutrition was also examined and lambs from restricted-fed ewes were found to have decreased birth weight and decreased postnatal growth rate (Hoffman et al., 2014, 2016a, 2016b). Despite decreased postnatal growth in lambs from restricted-fed ewes, these lambs also showed a significant increase in heart weight at 3 months of age, suggesting an underlying stress response or physiological condition (Hoffman et al., 2014, 2016a, 2016b). The increase in body weight and size of lambs from over-fed ewes is unlikely to be beneficial in the long-term due to the related increased adiposity of these animals (Hoffman et al., 2016a). Though over-fed ewes produce lambs with increased ADG and body weights, the carcass composition of these offspring contains increased adiposity with reduced muscle fiber diameter, reduced intramuscular fat, and reduced muscle tenderness, creating a poorer quality product for producers raising sheep for meat (Klont et al., 1998; Grunert et al., 2004; Reed et al, 2014; Cheng et al., 2015). Oxidative stress and systemic inflammation due to increased adiposity in offspring from both over- and under-fed ewes can cause health issues, such as obesity, metabolic syndrome, heart disease, and liver disease, reducing the welfare of livestock and their production efficiency (Southerland et al., 2006; Grattagliano et al., 2008; Fernandez-Sanchez et al., 2011; Cichoz-Lach and Michalak, 2014; Manna and Jain, 2015).

Changes in ADG and body weight in offspring from over- or under-fed mothers are associated with changes in the hormones that regulate growth and development throughout life. Growth hormone (GH), insulin-like growth factor 1 (IGF-1), and insulin-like growth factor binding proteins (IGFBP) are responsible for regulating the growth and development of many tissues, including muscle and adipose, which are both important to meat production (Klont et al., 1998; Bispham et al., 2003; Grunert et al., 2004; Cheng et al., 2015). Maternal nutrient restriction during early- and mid-gestation increases glucose exchange capacity and may alter offspring sensitivity to insulin, which promotes increased offspring adipose development (Heasman et al., 1998; Dandrea et al., 2001; Bispham et al., 2003; Symonds et al., 2012). In studies examining restricted maternal nutrition, lambs from restricted-fed ewes were found to have decreased circulating IGF-1 and IGFBP-3 concentrations, a possible explanation for the observed decrease in birthweight and postnatal growth rate of these lambs (Hoffman et al., 2014, 2016a, 2016b). The timing of under-nutrition during gestation is key in determining which tissues will be affected. If nutrient restriction is corrected, realimentation during gestation can allow for compensatory fetal growth, as evidenced by the increased circulating concentrations of IGF-1 in realimented twin fetuses (Field et al., 2015). These underlying mechanisms for altered ADG and bodyweight indicate that even when fed an appropriate diet, offspring exposed to nutrient excesses or restriction in utero will have reduced carcass quality and feed efficiency, which are important qualities in livestock production.

Beyond the effects of maternal nutrition during gestation on offspring growth and the hormones regulating growth, there is evidence that poor maternal nutrition during gestation affects offspring metabolism. Long-lasting effects on offspring metabolism can ultimately affect the health and productivity of offspring during their lifetimes (Bispham et al, 2003; Ford and Long, 2011). Both realimented and non-realimented fetuses showed negative effects of maternal diet restriction during gestation (Ford and Long, 2011; Field et al., 2015; Hoffman et al, 2016). Lambs from restricted- and over-fed ewes had greater baseline concentrations of insulin, and lambs from both the over-fed and restricted-fed ewes had greater insulin:glucose ratios than control lambs (Hoffman et al., 2016a, 2016b). Fetuses of non-realimented restricted-fed ewes also had decreased glucose concentration gradients which could indicate that the metabolism of these fetuses was programmed to function on a decreased plane of nutrition postnatally (Field et al., 2015). Additionally, the realimented fetuses were likely predisposed to insulin-resistance postnatally due to fetal exposure to increased insulin concentrations (Field et al., 2015). Lambs from over-fed dams were found to have increased leptin concentrations, suggesting the development of leptin resistance due to fetal exposure to increased leptin concentrations and subsequent increased adiposity (Ford and Long, 2011; Hoffman et al., 2014, 2016a, 2016b).

These findings suggest that excess or restricted maternal nutrition during gestation impacts the development of critical organs and predisposes offspring to metabolic disturbances from leptin and insulin resistance, affecting feed efficiency and animal health (Ford and Long, 2011; Aiken et al., 2016; Hoffman et al., 2014, 2016a, 2016b).

Skeletal muscle is particularly vulnerable to the effects of maternal nutrient restriction, as it is a lower priority tissue for nutrient partitioning during gestation compared with more critical organs, such as the brain, heart, and liver (Zhu et al., 2004). There is evidence to suggest that over- or under-feeding ewes during gestation affects the protein accumulation, muscle development, long-term metabolism, and carcass quality of their offspring through genetic and epigenetic alterations (Ulrey et al., 2005; Ford and Long, 2011; Altmann et al., 2012; Funston and Summers, 2013; Reed et al., 2014; Aiken et al., 2016; Hoffman et al., 2016a, 2016b). This affects meat quality as insufficient protein accumulation and muscle development reduces the tenderness and size of meat from the carcasses of effected animals. The timing of maternal nutrient restriction is critical in its effect on fetal muscle development, as primary myogenesis begins at approximately 32 to 38 days of gestation during embryonic development and secondary myogenesis begins at day 62 of gestation during fetal development in sheep (Maltin, 2008). Primary and secondary myogenesis determine the number of muscle fibers an individual will possess postnatally, and any subsequent muscle mass accumulation is hypertrophic rather than hyperplastic (Rehnfeldt and Kuhn, 2008). This is a possible explanation for how maternal nutrient restriction during late gestation reduces satellite cell density and reduces the size but not the number of fetal muscle fibers, while nutrient excess during late gestation affects muscle fiber size without increasing muscle fiber number (Woo et al., 2011; Du et al., 2013, 2015). Nutrient excess during mid-gestation can promote muscle development by increasing muscle fiber number and altering muscle fiber cross-sectional area, thereby increasing overall offspring muscle volume, while also altering muscle fiber type ratios and increasing offspring adiposity at birth, which affects meat palatability through manipulation of maternal nutrition based on an understanding of the timing of myogenesis and adipogenesis (Bee, 2004; Bayol, et al., 2005; Woo et al., 2011). The most important tissues for meat sales are muscle and fat, as muscle becomes meat and the fat content of muscle influences tenderness and palatability (Klont et al., 1998; Grunert et al., 2004; Cheng et al., 2015). As discussed, both tissues can be affected throughout the body by alterations in offspring metabolism and growth when exposed to over- or under-nutrition during gestation (Maltin, 2008; Du et al., 2010, 2011; Woo et al., 2011; Reed et al., 2014; Hoffman et al., 2016a, 2016b). These clear effects on muscle growth affect meat quality and offspring health, increasing feed cost of production per animal and are therefore important for sheep producers to understand, particularly those producers utilizing their flocks for meat production (Klont et al., 1998; Grunert et al., 2004; Cheng et al., 2015).

Another important factor for meat quality, intramuscular fat, also known as marbling, is essential to the palatability of meat, and a large percentage of fibro/adipogenic progenitor cells are formed during fetal and neonatal development (Tong et al., 2008; Yang et al., 2013). An effect of maternal nutrition on the fibrogenesis and collagen content in fetal skeletal muscle and a positive correlation between the responses of adipose and muscle tissue can be expected in response to maternal nutrition due to the shared fetal cell line of adipogenesis and fibrogenesis (Du et al., 2015). The development of adipose tissue is also closely related to the development of the capillary network in utero, which are affected by maternal nutrient restriction, as under-feeding during gestation inhibits vascular epithelial growth factor expression in microvascular and aortic endothelial cells, decreasing angiogenesis (Khorram et al., 2007). While adipocyte numbers may be decreased within muscles due to maternal nutrient restriction during late gestation, adipose is highly plastic and compensatory growth contributes to the overall increased adiposity of offspring born to nutrient restricted mothers in sheep and cattle (Zhu et al., 2004; Funston, et al, 2010; Funston and Summers, 2013; Du et al., 2013, 2015). However, maternal over-nutrition during late gestation in sheep also poses a problem for offspring development, increasing offspring intramuscular adipocyte density and increasing neonatal intramuscular adiposity (Yan et al., 2011; Huang et al., 2012). The alteration of adipocyte numbers and location in the body due to excess- or restricted-maternal nutrition combined with the plasticity of adipocytes leads to reduced meat quality and increased carcass adiposity of offspring, reducing marbling while increased adipose storage is directed into extra-muscular adipocytes.

Maternal programming clearly has an effect on offspring meat quality and productivity, and it also plays a role in wool production throughout the adult life of affected offspring. During gestation fetal sheep develop broad primary follicles from days 60 to 90 post-conception, and fine secondary follicles from day 90 post-conception to birth, setting follicle density before birth (Kelly et al., 1996; Paganoni and Roberts, 2018). Fiber density is directly related to the fiber diameter ratio and fleece weight of a ewe’s offspring throughout their productive lives (Paganoni and Roberts, 2018). Underfeeding ewes during gestation can affect the number of hair follicles developed by the fetus, with the greatest effect of undernutrition on fine secondary follicle development between 115 and 135 days of gestation and permanently altering offspring fiber ratios (Hutchison and Mellor, 1983; Kelly et al., 1996; Paganoni and Roberts, 2018). Even seasonally expected feed restriction from forage quality changes can have an effect on secondary to primary fiber ratios, resulting in decreased ratios of fine secondary fibers to broad primary fibers in adult offspring previously exposed to undernutrition during gestation (Kelly et al., 2006). These alterations in fleece weight and fiber quality can notably affect the profitability of sheep production to the detriment of the producer (Kelly et al, 2006; Young et al., 2011).

While maternal nutrition has a striking influence on offspring development and postnatal production efficiency, other factors also contribute to the development of fetuses. Of particular interest to sheep producers is the effect of litter size on fetal development, and subsequent offspring productivity. Compared with singleton pregnancies, twin pregnancies generally show a decreased effect when exposed to maternal nutrition restriction which is likely due to the naturally occurring intrauterine growth restriction (IUGR) in twin pregnancies (Field et al., 2015). Due to the possibility of different degrees of effect from the same maternal nutrient management, it would be beneficial for offspring from different litter sizes to be managed differently, both pre- and postnatally. If producers do not know the litter sizes of their ewes, it becomes impossible for the feeding management of pregnant ewes to match their true nutritional needs. In order to identify pregnancies with multiple fetuses from singleton pregnancies, pregnancy confirmation methods that rely on more than monitoring breeding and ewe body weight need to be used. Specifically, ultrasonography is useful for diagnosing pregnancy, gestational age, and the number of fetuses and can be conducted most successfully during early gestation (Jones et al., 2016; Jones and Reed, 2017). Considering the impact that maternal nutrition has on fetal development and offspring productivity postnatally, as well as the effect of litter size on the degree of effect from maternal nutrition, increased use of the accessible management tools available would allow sheep producers to improve their production efficiency and flock management.

The findings discussed above are important as they quantify the effects that varying gestational nutrition can have on offspring productivity, which is of concern for livestock producers who are interested in improving the production efficiency and health of their animals. In particular, with the understanding that maternal nutrition during gestation has an important role in the future health and development of offspring, and the role the sheep industry possesses within the national economy, we needed to understand how New England sheep producers manage their flocks in comparison with the national standard. Thus, we looked for information on the overall and region specific management practices of sheep producers in the United States.

IV. Sheep Management Practices

To remedy the expected food shortage and continue improving the productivity of livestock industries, livestock production capacity and efficiency must be increased. One way to accomplish these goals is through the understanding and manipulation of animal management practices. To understand how management practices can be used to improve production we must understand which management practices influence production efficiency and animal welfare, as well as how they do this. Nutrition is a costly and key management practice in livestock production (Thelen, 2017; Roberts, 2018). Nutrition management practices vary widely based on region, farm size, and personal preference (USDA, 2012).

All creatures acquire important nutrients required for homeostasis from their diets. Carbohydrates, proteins, and lipids are required for cellular respiration, energy storage, and biosynthesis during every stage of life, such as growth, reproduction, and maintenance (Campbell et al., 2008). More specifically, carbohydrates are required as a source of organic carbon and proteins are required as a source of organic nitrogen and amino acids (Campbell et al., 2008). Essential nutrients differ species to species and must be obtained from an organism’s diet, as they are molecules that cannot be synthesized by the organism, such as specific amino acids, fatty acids, vitamins, and minerals (Campbell et al., 2008). The amount of each nutrient the diet provides is also important, as an excess of some minerals or vitamins can result in toxicity and disruption of the homeostatic balance, while a deficiency of essential nutrients can lead to metabolic dysfunction (Campbell et al., 2008).

The ratios and amount of nutrients required by an animal from dietary sources also changes over the lifespan of that animal (Campbell et al., 2008; NRC, 2008). In one study, ewes (F0) were subjected to maternal overnutrition during gestation and their female offspring (F1) were then raised on a control diet through adulthood (Pankey et al., 2017). The F1 ewes were then bred, and their female offspring (F2) were also raised on a control diet (Pankey et al., 2017). The F2 generation ewes had increased blood cortisol concentrations and insulin resistance and F2 rams had increased body mass compared with control lambs when exposed to an ad libitum feeding trial as adults (Pankey et al., 2017). Growing animals require increased protein compared with adult animals at maintenance, and during reproduction the overall nutrient requirements are also increased for the dam and her developing offspring (NRC, 2008). The National Research Council has developed clear recommendations for sheep nutrition at various stages of life (NRC, 2008). These recommendations include the maintenance of adult ewes, nutrition during the different stages of gestation, the recommended diet for a lactating ewe nursing different litter sizes, and various ages of lambs as they grow, including replacement lambs separated by sex (NRC, 2008). These recommendations also describe the recommended composition of diets including forage and concentrate (NRC, 2008). The recommended percentage of the diet that is concentrate changes through different life stages, as do the recommended percentages of key nutrients such as crude protein, calcium, phosphorous, and vitamins A and E (NRC, 2008). The clear evidence of the intergenerational impact that maternal or grandmaternal over- and under-nutrition during gestation has on offspring productivity, despite appropriate postnatal offspring diets, reinforces the importance of correct nutritional management for sheep. Concern regarding livestock gestational nutrition may even be greater than the concern for human health, as animals used for meat production spend a larger percentage of their lives in the womb than longer-lived species such as humans.

When examining nutrient requirements of sheep, management style and the location of farms can have a substantial effect on the diet of a flock. On range, sheep encounter energy, protein, phosphorus, and vitamin A deficiencies in forage that can negatively impact their productivity (Holechek and Herbel, 1986). Considering how important these nutrients are to the health and development of sheep, the lack of energy, protein, phosphorous, and vitamin A during periods of time or throughout the year can pose a significant threat to the health and productivity of sheep flocks on range. Sheep may also be exposed to an excess of nutrients under intensive management, through certain management practices such as flushing, feeding pregnant ewes for twins without knowing actual litter sizes, or the excess provision of concentrate in their diets in ad libitum feeding systems (Bermudez et al., 1989; Bøe et al, 2012). During nutritional excess or restriction, the ewe is the only avenue for nutrient delivery to the growing fetuses in her uterus.

As previously mentioned, it is important to understand how nutrition during gestation affects maternal programming to best prevent negative results through the use of appropriate management practices. Understanding how management practices contribute to maternal nutrition is also important for the improvement of production efficiency. Therefore, knowing which practices sheep producers use for the management of their flocks is valuable for the future improvement of sheep management based on the understanding of maternal programming, maternal nutrition, and how management practices contribute to both of these factors for offspring productivity.

V. USDA Sheep Producer Surveys & Agricultural Needs Assessment

In the search for known information regarding management practices of American sheep producers, and New England sheep producers in particular, surveys conducted in 1996, 2001, and 2011 by the National Animal Health Monitoring Service (NAHMS) under the United States Department of Agriculture (USDA) provided important information (USDA, 2012). However, the USDA surveys were not disseminated in any New England state (CT, MA, ME, NH, RI, VT) during the years they were conducted. Additionally, it is unlikely that the states considered to be the East in these surveys are truly representative of the way flocks are managed in New England, as they ranged from New York, Pennsylvania, and Virginia to Minnesota, Iowa, and Missouri (USDA, 2012). This is because the majority of livestock operations in the surveyed states are larger farms that utilize pastures and rangeland to feed their flocks, while the availability of land for larger farms in New England is a rarer commodity to which most sheep producers do not have access (Heimlich and Barnard, 1992; USDA, 2012). New England livestock producers also have to contend with harsh winters and different geography than present in the states considered to be the East by the USDA for their surveys.

Almost one-half of the total U.S. sheep inventory in 2011 was farmed in California, Colorado, Montana, South Dakota, Texas, and Wyoming, though there was a decrease in sheep population numbers in these states between 2001 and 2011 (USDA, 2012). Other states with smaller sheep populations saw a growth of 11 to 47% in their sheep populations from 2001 to 2011, including Arizona, Missouri, Virginia, and Wisconsin (USDA, 2012). The surveyed states had a much broader variety of management types than is expected from New England producers, including feedlots, open or fenced range, and pasture (USDA, 2012). In terms of flock purpose, the vast majority of producers in surveyed states used their flocks to produce meat as their primary purpose, and as flock size increased it was more likely that the sheep would be managed on range, rather than pastures (USDA, 2012). Additionally, farms used for statistical analysis of these surveys ranged in size from 20 ewes to over 500 ewes, but did not include the smallest farms that are likely to be more common in New England (USDA, 2012). While much of the information garnered from the USDA sheep producer surveys may yield similar results to the management practices of New England's producers, the majority of farms that contributed to these data do not match the expectations held for smaller, more intensively managed flocks that are more common in the Northeast (Heimlich and- Barnard, 1992; USDA, 2012).

Needs assessment is an important methodological tool Extension professionals use to improve understanding of production goals and producer needs. A need is the quantifiable gap between the current reality and the desired state of reality (Altschuld and Kumar, 2010). Without identifying the discrepancy between these conditions, a need cannot be directly identified (Altschuld and Kumar, 2010). The needs assessment process takes into account not simply this discrepancy between reality and a goal state, but also the required strategies to identify and deliver appropriate solutions for the identified discrepancies (Altschuld and Kumar, 2010). Needs assessment may fail even if it is successful in identifying needs if it does not also lead to action to address identified discrepancies (Altschuld and Kumar, 2010). Altschuld and Kumar (2010) propose a three-phase, 14-step approach to the needs assessment process. Phase one is pre-assessment, to identify the focus of the needs assessment through the formation of a group to guide the process by focusing on the main concerns and discovering what is already known in order to identify needs (Altschuld and Kumar, 2010). Assessment is phase two, entailing a thorough assessment of the discrepancies between identified needs from phase one, including discrepancy classification, prioritization of discrepancies, and analyzing the causes of given needs (Altschuld and Kumar, 2010). The final phase of Altschuld and Kumar's (2010) proposed needs assessment approach is post-assessment, when solution strategies are finalized and actions to resolve needs are planned and implemented. Phase three concludes with documentation and evaluation of the needs assessment process itself, with the goal of revisiting and reusing the resulting information in future needs assessments (Altschuld and Kumar, 2010). Well-designed needs assessment allows Extension agents to design programming and services that support the goals of their constituents (Turkson and Naandam, 2003; Barron, 2009; Layman et al., 2013; Whitaker, 2018).

Many needs assessment methods allow Extension agents to gain a thorough understanding of the jobs that clients need information services to accomplish through the use of surveys and facilitated discussions with focus groups (Layman et al., 2013; Whitaker, 2018). For example, the Jobs To Be Done (JTBD) framework allows for the assessment of both macro-level program needs and the micro-level needs of end users (Whitaker, 2018). Programs and services developed based on JTBD assessment can be used to address information non-consumption through understanding causality and addressing any unmet client needs of existing resource by engaging prospective clients in the product development process through constructive feedback (Whitaker, 2018). Other needs assessment tools such as surveys can be used to great effect in combination with focus groups or when facilitated discussions are unfeasible (Turkson and Naandam, 2003; Barron, 2009). Needs assessment models are versatile and applied to a variety of project topics within the scope of Extension services, from climate change to agriculture, with target audiences varying from individuals to industry professionals (Turkson and Naandam, 2003; Barron, 2009; Altschuld and Kumar, 2010; Layman et al., 2013; Whitaker, 2018). Appropriate needs assessment at the start of program development increases the effectiveness of Extension products and outreach by engaging with the needs of local audience members as expressed by audience representatives, rather than through what academics may believe the needs of a given audience to be (Turkson and Naandam, 2003; Barron, 2009; Layman et al., 2013; Whitaker, 2018).

Minimal region specific knowledge regarding New England sheep production was available during the phase one literature search for known information on this topic. Due to the clear lack of region specific information on sheep management practices, and the obvious importance of maternal nutrition for offspring growth and development throughout life, it was necessary to fill this knowledge gap. To this end, an exploratory survey was conducted with the objective of developing a baseline understanding of New England’s sheep production management practices and future outreach opportunities in the region.

Materials & Methods

The survey questionnaire was developed through group workshopping, and resulted in a questionnaire of 12 questions that were simple and easy to answer that covered topics of interest in regard to breeding and feeding management in the New England sheep industry (Appendix A). A select group of sheep producers were asked for feedback during the development of the survey questionnaire, and changes were made accordingly. Once the questionnaire was finalized, it was entered into Qualtrics for future distribution via email.

The pool of potential participants was curated through several means. First, many New England sheep producer associations keep public member lists, which were combined and then checked to ensure that those producers listed were still reasonably likely to be active in sheep production. The Blue Ribbon Sheep Fair is held on the University of Connecticut campus, and a table was set-up to spread information about the survey project and allow producers to sign-up to participate in the survey. Additional participants were accumulated through word of mouth and emailed to ensure that they were on the list of potential participants. The cumulative list of New England sheep producers was then imported into Qualtrics for distribution.

The survey was initially distributed on July 5, 2017 to 286 sheep producers in New England. Additional distributions were scheduled when producers emailed asking to participate in the survey who had not been on the initial distribution list. Those producers who had not started or had started and not finished the survey received a reminder email on August 2, 2017. A final reminder email and thank you was sent to all producers on September 1, 2017, roughly a week before the survey was closed and response analysis began. The minimum target for overall response rate was 20.0%.

Once the survey was closed, responses were evaluated for how well the questionnaire met the needs of our inquiry and write-in responses were recoded into quantifiable values for analytical purposes. The variety of breeds in the region was much greater than expected, and breeds were then quantified as how many breeds producers owned. Additional methods of pregnancy confirmation were written in and if found to be named by at least three separate respondents they were removed from the ‘other’ group and quantified. Sources of feed information and methods of feed amount determination were also written in with more variety than in the provided answer options. Those responses found to be common were removed from the ‘other’ category and quantified.

The data were exported from Qualtrics into a Microsoft Excel file that was imported into SPSS (IBM Corp., 2017) for further quantification and analysis. SPSS was used to analyze and visualize data frequencies. Correlations between variables were analyzed in SPSS through the crosstab function with Phi and Chi-square tests, and post-hoc Cramer’s V tests. Significance was set to $P \leq 0.05$.

Results

Producer Management Practices as Frequencies

Flock Demographics

The minimum target for overall response rate was 20.0%; the actual response rate received was 33.6% overall, with a minimum of 17.9% and a maximum of 61.1% by state (Table 1). Out of 96 total respondents to the survey, the greatest percentages were residents of Connecticut and Maine (Table 2).

The greatest percentage of respondents (37.5%) have flocks in the 11 to 25 range, and over one-half of respondents (61.5%) have flocks between 11 to 50 animals in size (Table 3). The majority of respondents (79.2%) use their flocks to produce meat, although a large number (61.5%) also produce fiber (Table 4). There is an overlap of 40.6% producers who use their flocks for both meat and fiber production. Only 4 flocks produced sheep milk for sale, and none of those flocks produce milk as the sole product (Table 4). When surveyed regarding which specific breeds they own, producers named over 40 breeds in New England, indicating a large diversity of breeds in the region (Appendix B). However, the majority of sheep producers in New England (63.5%) only own 1 breed of sheep (Table 5).

Breeding Practices

Most sheep producers target the months of January through May for lambing season (Early and Late Spring; Table 6). A smaller number also target Fall (September through December; Table 6). Those producers that include summer (June through August) in their lambing season allow for lambing to take place throughout the year (Table 6). Ram marking, where the ram wears a colored wax crayon affixed to a chest harness, is used by 42.7% of sheep producers, while only 28.1% of producers use ultrasound for pregnancy confirmation (Table 7).

The 6.3% who selected ‘other’ either use a blood test or have their veterinarian confirm pregnancy, though the specific method the veterinarian used was not specified (Table 7). Flushing is the technique of increasing caloric intake just before and during the breeding season in sheep. Producers reported approximately equal use of flushing or not utilizing this technique during breeding season amongst New England sheep producers (Table 8).

The majority of sheep producers (40.6%) obtain their feed information from a feed salesperson or producer (Table 9). Brochures and a veterinarian are utilized for information by 24.0% and 28.1% of producers, respectively; only 18.8% of sheep producers get feed information from Extension services (Table 9). The most commonly used method for determining how much to feed a flock is body condition score (BCS, 64.6%; Table 10). Additionally, 25.0% of New England sheep producers utilized a standard farm operating procedure, such as a standardized feed scoop or coffee can (SOP; Table 10). Only 2.1% of sheep producers in New England follow National Research Council (NRC) guidelines for the feeding of their flocks (Table 10). The majority (66.7%) of New England sheep producers also utilize BCS to monitor how well they are feeding their breeding ewes during gestation (Table 11). The calendar, or the timing of gestation per ewe, is used by 20.8% of sheep producers to adjust their feeding methods (Table 11). The vast majority (76.0%) of New England sheep producers do not have chemical analysis completed on their feed (Table 12). The most common combination of feed types used in New England are hay, fresh pasture, and concentrate (Fig 12). Fifty percent of sheep producers feed two types of feed and 31.3% feed three types of feed during gestation (Table 14). It is likely that these types of feed are hay and concentrate, or hay, concentrate, and pasture. Only 12.5% of sheep producers feed only one type of feed (Table 14). The majority of producers prefer hands-on and visual learning styles; a minority percentage (25.0%) prefer audio (Table 15).

Correlations Between Producer Management Practices

Correlations by State

Correlations of state by flock size (P = 0.802), flock purpose (P = 0.880), number of breeds owned (P = 0.843), lambing season (P = 0.792), flushing (P = 0.742), method to determine amount of feed (P = 0.907), feed monitoring method (P = 0.669), feed analysis (P = 0.789), feed types (P = 0.398), number of feed types (P = 0.952), pregnancy confirmation method (P = 0.097), and preferred producer learning style (P = 0.825) were not found to be significant.

There was a correlation between state and source of feed information (P = 0.023; Table 16). The most common sources of feed information used by producers from Connecticut, Massachusetts, New Hampshire, and Rhode Island are feed salespeople or feed producers (Table 16). Feed salespeople and feed brochures were equally common among New Hampshire producers as sources of feed information (Table 16). The most common source of feed information used by producers from Maine is Extension agents (Table 16). Among producers from Vermont, the equally most common (33.3%) sources of feed information are feed brochures, state extension resources, other sheep producers, and personal research (Table 16).

Correlations of Management Practices

Correlations of flock size by flushing (P = 0.381), flock size by number of feed types (P = 0.641), flock size by pregnancy confirmation method (P = 0.273), flock purpose by flushing (P = 0.463), and flock purpose by feed analysis (P = 0.098) were not found to be significant.

There was a correlation of flock purpose by flock size (P = 0.014), with the greatest number of producers having flocks between 11 to 50 sheep that they use for both meat and fiber production (Table 17). The relationship between flock size and the number of breeds owned was significant (P < 0.001), with 30.2% of New England sheep producers owning one breed and a flock between 11 to 25 sheep in size (Table 18). The likelihood of owning a single breed decreases in flocks above 100 or more sheep in size, with the greatest percentage of flocks in this range being made of four or more breeds (Table 18). There was a correlation between feed type and flock size (P = 0.046; Table 19); the most common feed types used across all flock sizes are hay and concentrate, with pasture as the third most common feed type used across all feed sizes, though the greatest disparity between these three was seen among flocks with 11 to 50 sheep (Table 19).

The correlation between feed type used by producers and flushing (P = 0.154) was not found to be significant. In the correlation between feed type and the number of feeds used (P < 0.001), 50.0% of producers use two types of feed and feed hay, and 43.8% use two types of feed and feed concentrate (Table 20). Those producers who feed hay and concentrate have the greatest percentage of the use of feed analysis (20.8%), however, both feed types also have the greatest percentages of non-feed analysis use (Table 21). This is likely indicative of these feeds being the most commonly fed, rather than a statistical likelihood that either will make it more likely for a producer to use feed analysis. The correlation between feed type used by producers and the source of feed information is complex, as there are many sources of feed information. In order, the most common (>20.0%) information sources for producers who feed hay are a feed salesperson, a veterinarian, and brochures; while the most common sources of information for producers who feed concentrate are a feed salesperson and veterinarians (Table 22).

Discussion

In comparison with the sheep producer information from the national USDA survey data, New England sheep producers have smaller flocks that are more intensively managed. New England flock sizes are so small compared with the USDA categories that they would be listed as Small (20 to 99) or Very Small (1 to 19), and the Very Small flocks were not included in data analysis in the USDA report (USDA, 2012). Of New England sheep producers, 73.0% have flocks between 11 to 100 sheep, which is comparable with the USDA data that 73.1% of producers have flocks between 20 to 99 sheep (USDA, 2012). However, at the national level, those 73.1% of producers only account for 22.1% of the total sheep population in the United States (USDA, 2012).

The USDA conducted their survey in much the same way as our survey, allowing for double representation of farms in response to certain questions. Their purpose categories were meat, wool, milk, breeding or seedstock, competition or 4-H, and other, with 32.6% of sheep producers keeping their animals for more than one purpose (USDA, 2012). Nationally, meat production is a greater focus for sheep producers than wool production, with 81.6% of farms producing meat and only 15.8% of farms producing wool (USDA, 2012). In those states categorized as the East, 82.4% of producers produced meat and only 8.9% produced wool from their flocks (USDA, 2012). Similar to the findings in New England, national sheep producers did not focus on milk production, and only a small percentage produce it with their flocks (USDA, 2012). While New England producers are comparable with the national percentage of producers who use their flocks for meat production (79.2%), New England has a greater percentage of producers who produce wool (61.5%) than national producers, with a 40.6% overlap of New England producers who produce both meat and wool from their sheep flocks.

In New England, the majority of producers feed hay, and 79.2% also feed concentrate, while only 37.5% of producers utilize pasture in feeding their flocks. In contrast, fresh forage is the most utilized feed source by national sheep producers. The USDA reported that 46.0% of sheep producers use open or fenced range and 75.8% of producers use pasture, with an additional 37.9% of producers feeding their flocks in dry or feedlots (USDA, 2012). In those states considered to represent the East, 80.3% of sheep producers use pasture to feed their flocks (USDA, 2012). The USDA survey did not collect information regarding the supplementation of hay and concentrate for flocks, regardless of or in relationship with their use of pasture or range, and so a direct comparison of those feed types based on our data and the USDA survey is impossible. Additionally, while New England producers were asked where they received their feed information, the USDA asked about where sheep producers received their health information, with veterinarians viewed as the most important source for this type of information nationally (USDA, 2012). This also prevents a direct comparison, as health is a much broader topic than nutrition and the preferred source for nutrition information may differ from the preferred source for health information. A similar approximately equal use and non-use of flushing was seen both in New England and in the USDA survey, as 53.1% of New England producers flush their ewes before and during the breeding season and 52.8% of producers in the USDA survey use flushing as a reproductive technique (USDA, 2012). With the understanding of how maternal nutrition during gestation contributes to maternal programming and how different regions of the U.S. feed their flocks utilizing different management practices, it is important to improve producer understanding of the nutrition with which they are providing their breeding flocks.

Feed analysis is a simple, inexpensive method for improving diet calculations and ensuring that animals are being fed to meet their nutrient requirements. As previously discussed, all mammals require carbohydrates, proteins, and lipids from their diets (Campbell et al., 2008). Ruminants also require a certain amount of fiber from their diets for rumen health. If available forage has too much fiber content, it can reduce intake, limiting the usefulness of provided forages, even if they are otherwise nutritionally sound (Feist, 2011). In order to provide nutritionally sound rations for their animals, producers need to have an understanding of what their animals' needs are and what nutrients their feed contains. Forage quality and fiber content change throughout the year. Several factors can influence nutrient composition and forage fiber content, such as when plants are harvested during the year, plant maturity, weather conditions during plant growth, and storage losses (Bell, 1997; Corson et al., 1999; Feist, 2011; Van Saun, 2017). Wet chemistry analysis of feed has been considered a gold standard, but during the previous three decades near-infrared (NIR) spectroscopy has become an equally excellent method of feed analysis that is also cheaper than wet chemistry analysis (Corson et al., 1999; Van Saun, 2017). Most feed analysis companies are capable of conducting both methods of analysis on provided samples, depending on feed type compatibility (Dairy One, 2016; Van Saun, 2017). For example, one such company, Dairy One, can provide NIR spectroscopy analysis for grain or forage starting at $18 and basic wet chemistry analysis at $22.

Formulating a diet to meet the needs of sheep at their specific phases of production requires knowledge of both the nutrient requirements of the animals and the nutrient content of available feed. Considering the overall lack of feed analysis being done by sheep producers, it is an excellent opportunity to improve outreach and understanding regarding nutrition in general, and especially how nutrition during gestation can create lasting effects on offspring productivity.

While concentrate often comes with a nutrient analysis on the bag if bought as a bagged feed, the quality of hay and pasture both change throughout the year. The overall usage of hay (95.8%) by New England sheep producers is indicative of the importance for improving the usage of feed analysis in this region.

In addition to the importance of diet formulation during gestation, litter size can play a key role in the effect of maternal programming and the nutritional needs of ewe and fetuses. There is a notable difference between New England and the national statistics on pregnancy confirmation practices when comparing survey results. Of the farms possessing 20 to 99 sheep (Small) 22.6% use ram marking to confirm breeding, while only 6.2% use ultrasound technology for pregnancy confirmation and fetal counts (USDA, 2012). In New England, 41.7% of sheep producers use ram marking for pregnancy confirmation, and 28.1% utilize ultrasonography, likely due to the convenience of ram marking and the shorter distances veterinarians with ultrasound expertise likely need to travel to reach farms within New England compared to the larger states featured in the USDA survey. There may also have been an increase in ultrasonography over the six years between when the USDA survey was conducted and when the New England sheep producer survey was conducted.

Ultrasound technology has improved over the last twenty years, increasing the accessibility of this useful pregnancy management tool. Though it was first used in livestock in the 1980s, sheep producers have been slow to fully integrate it into their management practices, likely due to the expense of purchasing and developing expertise with ultrasound technology. There are two approaches for ultrasounding sheep: transrectally or transabdominally. Due to necessary methods of restraint, the transabdominal approach is easier, faster, and less stressful on ewes than the transrectal method (Jones et al., 2016; Jones and Reed, 2017). Ultrasonography is a useful management tool for sheep producers, as it enables not only the detection of pregnancy, but it can also be used to predict the number of fetuses a ewe is carrying and the gestational age of the offspring (Jones et al., 2016; Jones and Reed, 2017). Such information allows for the producer to improve nutrition management during gestation, rather than risking over- or under-nourishing the ewe and lambs. It is even possible to sex lambs in utero, with the greatest accuracy for both sexing and counting fetuses during the second month of gestation (Jones et al., 2016; Jones and Reed, 2017). Fetal growth can also be measured through transabdominal ultrasound, and irregularities in development can be observed early, which could allow for producers to intervene in a timely manner or be aware of which ewes may need assistance during parturition (Jones et al., 2016; Jones and Reed, 2017). Ultrasonography can enable sheep producers to improve gestational care of ewes and improve the outcomes and production efficiency of lambs, especially with the involvement of veterinary expertise. This makes the increased usage of ultrasonography an attainable opportunity for improved outreach among New England sheep producers. Considering the extensive practice required to gain expertise with ultrasonography for the identification of pregnancy and litter size, the most convenient avenue for sheep producers to incorporate ultrasonography into their management practices would be through the utilization of veterinarians with their own portable ultrasound machines and the existing expertise to use and interpret results accurately (Jones et al., 2016; Jones and Reed, 2017).

Integrating the use of ultrasonography into their management practices will enable producers to monitor fetal growth, gestational age, and fetal number, allowing for specific nutritional management of the ewe based on litter size (Jones et al., 2016; Jones and Reed, 2017). Increasing the use of feed analysis will empower producers to calculate rations more accurately, avoiding over- or under-feeding their sheep (Bell, 1997; Corson et al., 1999; NRC, 2008; Feist, 2011; Van Saun, 2017). Improving relationships between Extension and New England sheep producers will provide producers with increased access to production resources and information regarding best practices. Increasing ultrasonography integration, feed analysis use by producers, and the relationships between Extension and sheep producers will enable New England producers to improve their flock production performance in response to knowledge of the influence of maternal diet on offspring health. Without appropriate nutrient management during gestation, carcass quality decreases due to altered muscle development, decreased marbling, increased overall adiposity, and altered metabolic function leading to alterations in growth rate of offspring (Heasman et al., 1998; Dandrea et al., 2001; Zhu et al., 2004; Funston et al., 2010; Symonds et al., 2012; Du et al., 2013, 2015; Funston and Summers, 2013; Hoffman et al., 2014, 2016a, 2016b; Reed et al., 2014; Field et al., 2015). This knowledge and understanding of the importance of maternal nutrition and its effect on maternal programming should be utilized to help producers reach and surpass their production goals and inform the development of resources and outreach specific to the needs of New England's sheep producers.

Lambing seasons show similar trends between the USDA survey and the data presented here. The greatest percentage of lambs are born between January and May, with another notable percentage of lambs born between September and December, most likely to take advantage of the holiday season interest in lamb meat and live lambs (USDA, 2012). While there are certain management practices that New England sheep producers use in comparable measure with national sheep producers, there are enough differences between this region and the country as a whole to warrant a specific understanding of New England sheep production.

In light of the scarcity of sheep specific livestock Extension agents in the region, there are certain avenues ideal for improved outreach, resources, and understanding for Extension programs with the funding to pursue them. Extension services are under-represented as a utilized resource in most New England states, and the relationships between sheep producers and their local Extension agents require improvement on the part of Extension services to encourage and improve their communication with and support of producers. Specific topics which improved relationships with Extension services can focus on in the region are the use of ultrasound for the detection of pregnancy and litter size, the usefulness of feed analysis, and the ways that improved Extension-producer relations will increase the accessibility of resources for producers and their pursuit of increased production efficiency. These outreach and engagement programs could take the form of flyers, website posts, and face-to-face meetings among other program styles in order to open dialogue and engage with producers (Donovan, 2014; Lubell et al., 2014; Andrango and Bergtold, 2015).

Additionally, the information collected on preferred producer learning styles will aid in the improvement of Extension resources and outreach efforts, as it is important to match the preferred learning styles of the target audience in order to maximize the effectiveness of outreach and education (Franz et al., 2010; Raison, 2014; Andrango and Bergtold, 2015). While some New England universities and Extension websites host basic resources for sheep producers, it is more difficult to ascertain via these websites which Extension agent, if any, is an appropriate contact for more personal assistance. This also requires a sheep producer to initiate the request for assistance from Extension services, rather than utilizing a pre-existing relationship or structured educational resource. The first step towards improved support of New England's sheep producers is to develop improved relationships between Extension services and producers

(Franz et al., 2010; Donovan, 2014; Raison, 2014). Once there is open dialogue between sheep producers and their respective Extension agents, each state's Extension program can tailor any resources they have the funding and support to create to the needs of their specific sheep producers (Franz et al., 2010; Donovan, 2014; Lubell et al., 2014; Raison, 2014). Furthermore, dialogue between Extension agents and sheep producers may assist in the development of outreach and engagement resources for the general public (Donovan, 2014). As important as it is to improve livestock production efficiency and the resources available to producers, especially in light of current and impending food production shortages, it is equally important to improve outreach and information available to the wider public. By encouraging education and outreach to both audiences a lasting positive change is possible for the agriculture industry.

It is clear there is a domestic demand for sheep products, despite the reduction in the national sheep industry (Williams et al., 2007). The fact that half of the national demand for lamb is met through the import of lamb meat represents the potential room for domestic sheep industry growth to meet this demand, decrease the importation of lamb, and increase future promotion of mutton and lamb as nutrient dense lean meat (Williams et al., 2007). Due to the different geography and land use of New England compared to the Midwest and South, New England sheep producers have an overall different management style than the larger producers in the rest of the country. However, intensively managed sheep production is not unique to New England and resource improvements could be applicable outside of our region (Sebsibe, 2008). Considering the increase in global livestock populations and the drive towards increasing production efficiency, it is likely that improved resources and advancements made in New England sheep production may have international applications for producers looking to intensively manage their flocks (Sebsibe, 2008).

Limitations & Implications for Future Research

The data of interest inherently required self-reporting by sheep producers, and self-reported data has limitations based on human recollection and bias. Response rate can vary depending on the mode of survey administration and computer delivered surveys reduce some biases by increasing the sense of privacy the respondents feel while completing a survey (Evan and Miller, 1969; Sax et al., 2003). However, the knowledge that a survey is conducted by authority figures in a field of interest may invoke other biases, such as the social desirability bias. The social desirability bias occurs when respondents provide data they believe will be socially acceptable regardless of its veracity (van de Mortel, 2008). The influence of such biases are a given in the social sciences, though it is unlikely that bias had a significant impact on the data collected in this survey. Future surveys should be designed to maintain the minimal influence of possible biases inherent in self-reported data.

Based on the results of this survey, future iterations should be restructured to allow for easy correlation analysis using Likert scale or matrix style questions as the conducted survey was not designed with the goal of assessing correlations. Thus our data could not be compared with an expected model generated from previous national surveys to confirm the expectation that New England sheep producers were not represented by the national data.

The survey primarily investigated the management practices of sheep producers in New England and the questions developed for this survey focused on ascertaining such information. However, after analysis it was determined that it would also be beneficial to know how producers are selling their products, such as whole animals versus cuts of meat, what their relationships are with the meat processing pipeline, and whether they receive any net assets from their sheep production. Due to the nature of our research objectives our survey was not designed to gather data regarding the marketing and economics of individual sheep producers, however questions regarding these topics should be added to future survey iterations. The survey questions should also be expanded to cover additional topics of import to sheep production, including the economics and processing of sheep production in New England.

Though the pool of potential respondents was curated through state-based sheep association lists and word of mouth, the response rate by state was not equal. Some states, such as Rhode Island, had lower response rates than the targeted 20 percent for social science research. Such a limitation is expected in social science research, as respondents cannot be compelled to fill out surveys they are sent. This limitation may obscure possible state specific correlations of sheep management practices. In future, a greater effort could be made to correctly ascertain the precise population of sheep producers in each New England state and encourage them to participate in future iterations of this survey. A continuing census of sheep producers in each New England state would assist with understanding the response rate and demographic of any future surveys and any demographic changes, which could benefit efforts to encourage an increase in respondents. Our intention is to follow up on this project with additional similar surveys in three and six years.

Going forward, we plan to investigate how current sheep producer management practices meet the needs of their flocks by looking at a sampling of New England farms. Samples taken will include feed and relevant animal data, as well as each farm’s standard operating procedure. These data will be used to ascertain how well current producer practices fulfill the needs of the animals under their supervision, and to verify if expected weaknesses of the standard operating procedures of New England match up with the actuality of New England’s sheep and their needs.

Additionally, Extension or university personnel could meet with focus groups of New England sheep producers utilizing a facilitated discussion framework, such as the JTBD protocol previously discussed, to assess the true needs of the region's sheep producers, what considerations and concerns they have that may not be obvious to researchers, and what types and topics of outreach they may desire (Altschuld and Kumar, 2010; Whitaker, 2018). The results of such focus groups should be used to guide any resources or outreach programs that Extension services choose to pursue and develop to better support the region's sheep producers.

Table 1. Response Rate of New England Sheep Producers by State.

State	Producers E-Mailed	Response Rate
Connecticut	97	26.8%
Maine	67	40.2%
Massachusetts	49	38.8%
New Hampshire	18	61.1%
Rhode Island	39	17.9%
Vermont	19	31.6%

The total number of producers contacted via e-mail, by New England state, and the response rate of that total number of producers who participated in the survey.

Table 2. Participating Sheep Producers by State

State	Percentage of Producers
Connecticut	27.1
Maine	28.1
Massachusetts	19.8
New Hampshire	11.5
Rhode Island	7.3
Vermont	6.3

The percentage of sheep producers in each state of New England. Data are represented as a percent of the total number of survey respondents (96).

Table 3. Flock Sizes of New England Sheep Producers

Flock Sizes (sheep per flock)	Percentage of Producers
1 – 10	15.6
11 – 25	37.5
26 – 50	24.0
51 – 100	11.5
101 +	11.5

Data are represented as a percent of the total number of survey respondents (96).

Table 4. Flock Purpose of New England Sheep Producers

Flock Purpose	Percentage of Producers
Meat & Fiber	40.6
Meat	38.5
Fiber	20.8
Milk	4.2

Milk was produced by only 4 flocks, and never as the sole product of that producer. Data are represented as a percent of the total number of survey respondents (96). Respondents could select multiple responses.

Table 5. Number of Breeds Owned by New England Sheep Producers

Number of Breeds Owned	Percentage of Producers
1	63.5
2	17.7
3	10.4
4 +	8.3

Data are represented as a percent of the total number of survey respondents (96). Specific breeds named by producers in New England are listed in Appendix B.

Table 6. New England Sheep Producer Lambing Seasons

Time of Year	Percentage of Producers
Early Spring (Jan – Feb)	59.4
Late Spring (Mar – May)	59.4
Summer (Jun – Aug)	3.1
Fall (Sept – Dec)	14.6

Data are represented as a percent of the total number of survey respondents (96). Respondents could select multiple responses.

Table 7. Methods of Pregnancy Confirmation Used by New England Sheep Producers

Method of Pregnancy Confirmation	Percentage of Producers
Ram Marking	41.7
Ultrasound	28.1
Visual	13.5
Body Weight	10.4
Waiting/None	10.4
Other	6.3

Data are represented as a percent of the total number of survey respondents (96). Respondents could select multiple responses.

Table 8. The Use of Flushing by New England Sheep Producers

Flushing Use	Percentage of Producers
Yes	53.1
No	46.9

Data are represented as a percent of the total number of survey respondents (96).

Table 9. Nutrition Information Source Used by New England Sheep Producers

Nutrition Information Source	Percentage of Producers
Feed Salesperson	40.6
Veterinarian	28.1
Brochures	24.0
Extension	18.8
Internet	15.6
Other Producers	14.6
Other	13.5
Family	11.5
Research	8.3

The resources producers use to find information on feed and feeding techniques in New England. Data are represented as a percent of the total number of survey respondents (96). Respondents could select multiple responses.

Table 10. Methods of Feed Amount Determination Used by New England Sheep Producers

Methods of Feed Determination	Percentage of Producers
Body Condition Score or Body Weight	64.6
Standard Operating Procedure	25.0
Nutritionist	7.3
Other	6.3
Bag Label	3.1
National Research Council	2.1

Methods used by sheep producers to determine how much feed to provide to their flock. Data are represented as a percent of the total number of survey respondents (96). Respondents could select multiple responses.

Table 11. Methods of Feed Amount Monitoring Used by New England Sheep Producers

Methods of Feed Monitoring	Percentage of Producers
Body Condition Score	66.7
Calendar	20.8
Body Weight	8.3
Visual	4.2
Other	42

Producer methods for monitoring how well their feeding protocol is meeting the needs of their flock. Data are represented as a percent of the total number of survey respondents (96). Respondents could select multiple responses.

Table 12. Feed Analysis Use by New England Sheep Producers

Feed Analysis Use	Percentage of Producers
No	76.0
Yes	24.0

Producers were asked if they send their feed out for analysis through companies such as Dairy One. Data are represented as a percent of the total number of survey respondents (96).

Table 13. Types of Feed Used by New England Sheep Producers

Feed Type	Percentage of Producers
Hay	95.8
Concentrate	79.2
Pasture	37.5
Other	9.4
Haylage	7.3
Corn Silage	3.1

Data are represented as a percent of the total number of survey respondents (96). Respondents could select multiple responses. Six participants out of 96 also supplement with minerals, which was included in the ‘Other’ category for the purpose of this analysis.

Table 14. Number of Feed Types Used by New England Sheep Producers

Number of Feed Types	Percentage of Producers
1	12.5
2	50.0
3	31.3
4 +	6.3

Data are represented as a percent of the total number of survey respondents (96).

Table 15. Preferred Learning Styles of New England Sheep Producers

Preferred Learning Style	Percentage of Producers
Hands-on	85.4
Visual	79.2
Audio	25.0

Data are represented as a percent of the total number of survey respondents (96). Respondents could select multiple responses.

Table 16. Correlation Between Feed Information Source and State

		State					
		CT	**ME**	**MA**	**NH**	**RI**	**VT**
Feed Information Source	**Feed Salesperson**	53.8	14.8	47.4	45.5	85.7	16.7
	Brochures	15.4	14.8	26.3	45.5	42.9	33.3
	Family	19.2	3.7	5.3	18.2	28.6	0.0
	Extension	15.4	33.3	10.5	9.1	0.0	33.3
	Experience	0.0	11.1	5.3	9.1	14.3	16.7
	Other Producers	7.7	18.5	10.5	27.3	0.0	33.3
	Veterinarian	46.2	22.2	26.3	9.1	28.6	16.7
	Research	7.7	7.4	5.3	9.1	0.0	33.3
	Internet	19.2	18.5	15.8	18.2	0.0	0.0
	Other	15.4	7.4	10.5	36.4	0.0	16.7
Number of Respondents		25	27	19	11	7	6

P = 0.023. Data are represented as a percent of the number of survey respondents in each state.

Table 17. Correlation Bewteen Flock Purpose by Flock Size

		Flock Purpose		
		Fiber	**Meat**	**Milk**
Flock Size	**1 – 10**	9.4	13.5	0.0
	11 – 25	28.1	25.0	2.1
	26 – 50	14.6	19.8	0.0
	51 – 100	2.1	10.4	2.1
	100 +	7.3	10.4	0.0

P = 0.014. Data are represented as a percent of the total number of survey respondents (96).

Table 18. Correlation Between Flock Size and Number of Breeds Owned

		Breed Number Owned			
		1	**2**	**3**	**4+**
Flock Size	**1 - 10**	11.5	2.1	2.1	0.0
	11 - 25	30.2	3.1	3.1	1.0
	26 - 50	15.6	7.3	0.0	1.0
	51 - 100	5.2	3.1	2.1	1.0
	100 +	1.0	2.1	3.1	5.2

$P < 0.001$. Data are represented as a percent of the total number of survey respondents (96).

Table 19. Correlation Between Flock Size and Feed Type

		Feed Type					
		Pasture	**Hay**	**Concentrate**	**Haylage**	**Corn Silage**	**Other**
Flock Size	**1 - 10**	6.3	14.6	10.4	1.0	0.0	0.0
	11 - 25	9.4	37.5	30.2	1.0	1.0	5.2
	26 - 50	10.4	24.0	19.8	1.0	0.0	3.1
	51 - 100	5.2	9.4	9.4	3.1	0.0	1.0
	100 +	6.3	10.4	9.4	1.0	2.1	0.0

$P = 0.046$. Data are represented as a percent of the total number of survey respondents (96).

Table 20. Correlation Between Feed Type and Number of Feeds Used

		Number of Feeds Used			
		1	**2**	**3**	**4+**
Feed Type	**Pasture**	1.0	5.2	26.0	5.2
	Hay	10.4	50.0	29.2	6.3
	Concentrate	0.0	43.8	30.2	5.2
	Haylage	1.0	1.0	3.1	2.1
	Corn Silage	0.0	0.0	1.0	2.1
	Other	1.0	1.0	5.2	2.1

$P < 0.001$. Data are represented as a percent of the total number of survey respondents (96).

Table 21. Correlation Between Feed Type and Use of Feed Analysis

		Feed Analysis	
		Yes	No
Feed Type	Pasture	12.5	25.0
	Hay	20.8	75.0
	Concentrate	20.8	58.3
	Haylage	5.2	2.1
	Corn Silage	1.0	2.1
	Other	3.1	6.3

P = 0.003. Data are represented as a percent of the total number of survey respondents (96).

Table 22. Correlation Between Feed Type and Feed Information Source

		Feed Type					
		Pasture	Hay	Concentrate	Haylage	Corn Silage	Other
Feed Information Source	Feed Salesperson	13.5	39.6	36.5	1.0	3.1	4.2
	Brochures	8.3	24.0	18.8	2.1	0.0	3.1
	Family	5.2	11.5	10.4	0.0	0.0	2.1
	Extension	6.3	17.7	12.5	3.1	0.0	2.1
	Experience	2.1	5.2	5.2	1.0	1.0	1.0
	Other Producers	6.3	14.6	10.4	0.0	0.0	2.1
	Veterinarian	9.4	28.1	26.0	4.2	1.0	1.0
	Research	4.2	8.3	5.2	1.0	1.0	2.1
	Internet	10.4	14.6	12.5	1.0	0.0	3.1
	Other	4.2	12.5	11.5	0.0	0.0	3.1

P = 0.049. Data are represented as a percent of the total number of survey respondents (96).

Table 23. Correlation Between Preferred Learning Style and Flock Size

		Flock Size				
		1 - 10	11 - 25	26-50	51-100	101+
Preferred Learning Style	Hands On	10.4	35.4	21.9	9.4	8.3
	Visual	13.5	30.2	17.7	8.3	9.4
	Audio	0.0	11.5	3.1	7.3	3.1

P = 0.010. Data are represented as a percent of the total number of survey respondents (96).

Appendix A. Questionnaire Received by New England Sheep Producers

1. What size is your current flock?
   1-10 11-25 26-50 50-100 101 or more

2. What is the main purpose of your flock? Check all that apply.
   Meat Fiber Milk

3. What breed do you currently own? Check all that apply.
   Dorset Southdown Shropshire Border Leicester
   Hampshire National Colored Other (please explain)

4. What time of year do you usually target for lambing? Check all that apply.
   Early Spring (Jan-Feb) Late Spring (Mar-May)
   Summer (June-Aug) Fall (Sept – Dec)

5. Do you flush ewes before breeding?
   Yes No

6. How do you determine the amount of feed to provide pregnant ewes?
   Body condition score or Body weight National Research Council
   Nutritionist recommendation Feed bag recommendation
   Standard farm practice (i.e., coffee can, scoop) Other (please explain)

7. How do you monitor your feeding management during gestation?
   Body weight Body condition score
   Calendar Other (please explain)

8. Do you send your feed out for analysis (via Dairy One or another company)?
   Yes No

9. During gestation, what type of feed do you usually feed ewes? Check all that apply.
   Pasture Hay Corn Silage
   Concentrate Other (please explain)

10. What methods do you use for pregnancy confirmation?
    Body weight Ram marking Ultrasound
    Veterinarian Other (please explain)

11. Where do you go for feed and nutrition information? Check all that apply.
    Feed salesperson Family State Extension Agent
    Veterinarian Brochures Other (please explain)

12. What is your learning style? Check all that apply.
    Visual Audio Hands-on

Appendix B. Breeds of New England, by frequency of farms. The number of farms is included in parentheses.

1. Southdown (13)
2. Border Leicester (12)
3. Dorset (11)
4. Crossbreeds (10)
5. Katahdin (9)
6. National Colored (8)
7. Romney (8)
8. Shetland (8)
9. Hampshire (7)
10. Dorper (6)
11. Oxford (6)
12. Finn (5)
13. Coopworth (4)
14. Corriedale (4)
15. Lincoln (4)
16. Icelandic (4)
17. Shropshire (3)
18. Texel (3)
19. Jacob (3)
20. Tunis (2)
21. Suffolk (2)
22. Gotland (2)
23. Scottish Blackface (2)
24. Cheviot (3)
25. Merino (3)
26. Mule (2)
27. Cotswold (2)
28. Gulf Coast Native (2)
29. CVM/Romeldale (2)
30. East Friesian (2)
31. Olde English Babydoll Southdown (1)
32. Cormo (1)
33. Santa Cruz (1)
34. Polypay (1)
35. Kerry Hill (1)
36. Polworth (1)
37. Columbia (1)
38. Montadale (1)
39. Navajo Churro (1)
40. Painted Desert (1)
41. Leicester Longwool (1)

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